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RESEARCH MEMORANDUM

TRANSONIC AERODYNAMIC CHARACTERISTICS IN PITCH OF A W-WING HAVING 60° 48' PANEL SWEEP, ASPECT RATIO 3.5, AND TAPER RATIO 0.25

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

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SUMMARY

An investigation to determine the transonic aerodynamic characteristics of a W-plan-form wing of aspect ratio 3.5, taper ratio 0.25, 60° 48' panel sweep was performed in the Langley high-speed 7- by 10-foot tunnel by using a small reflection plane over which high subsonic and low supersonic Mach numbers are obtained. Limited comparisons are made with sweptback-wing data to determine the effectiveness of the wing modification which resulted in the W plan form.

For the lift range investigated and at a Mach number of 0.80, the results of this investigation, compared with sweptback-wing data, indicate that use of the W plan form markedly reduced the severity of the pitching-moment break. Minimum drag characteristics indicated a relatively low drag at supersonic speeds; an estimate of the minimum drag at a Mach number of 1.00 indicates a major portion of the sweep effect was still retained. The drag due to lift of the W-wing was slightly higher than that of the swept wing at the lower subsonic Mach numbers at which comparable data were available.

INTRODUCTION

Many of the sweptback wings currently being investigated have exhibited undesirable high-lift pitching-moment characteristics at transonic speeds. Previous wind-tunnel investigations have indicated that the conversion of the swept wing into a W-plan-form wing offers a means of obtaining improved longitudinal stability characteristics. Available high-speed W-wing data, however, heretofore have been largely restricted to relatively thick high-aspect-ratio wings (refs. 1 and 2).

The purpose of this investigation was to obtain wing-alone data at transonic speeds for a relatively low-aspect-ratio thin highly swept W-wing. The investigation was conducted in the Langley high-speed 7- by 10-foot tunnel by using a small reflection plane over which high subsonic and low supersonic Mach numbers are obtained. The W-wing had 60° 48' panel sweep, an aspect ratio of 3.5, and taper ratio of 0.25. Airfoil sections were NACA 64A005. Lift, drag, pitching-moment, and bending-moment data are presented for Mach numbers of 0.70 to 1.10. Limited comparisons are made with the sweptback-wing data of reference 3.

COEFFICIENTS AND SYMBOLS

All data presented herein are referred to the wind axes. Pitching moments are presented about the 0.25 mean aerodynamic chord.

C_L lift coefficient, $\frac{\text{Twice semispan lift}}{qS}$

C_D drag coefficient, $\frac{\text{Twice semispan drag}}{qS}$

C_m pitching-moment coefficient, $\frac{\text{Twice semispan pitching moment}}{qS\bar{c}}$

C_B bending-moment coefficient due to lift about root chord,

$$\frac{\text{Twice semispan bending moment}}{\frac{qSb}{2}}$$

$C_{D_{min}}$ minimum drag coefficient at $C_L = 0$

C_{D_L} drag due to lift, $C_D - C_{D_{min}}$

c_l local section lift coefficient

y_{cp} lateral center of pressure, $\left(\frac{100 \times \partial C_B}{\partial C_L}\right)_{\alpha=0}$ percent semispan

a.c. aerodynamic center, percent mean aerodynamic chord

q effective dynamic pressure over span of model, $\frac{1}{2}\rho V^2$, lb/sq ft

ρ air density, slugs/cu ft

V	free-stream velocity, ft/sec
S	twice area of semispan model, sq ft
b	wing span (twice semispan), ft
$\bar{c}$	mean aerodynamic chord of wing, using theoretical tip, $\frac{2}{S}\int_0^{b/2} c^2 dy$, ft
c	local wing chord, ft
c_{av}	average wing chord, $\frac{S}{b}$, ft
y	spanwise distance from plane of symmetry, ft
M	effective free-stream Mach number
M_l	local Mach number
α	angle of attack of root chord, deg
$\frac{cc_l}{c_{av}C_L}$	span-loading coefficient
R	Reynolds number, based on $\bar{c}$

MODEL

The W-plan-form model with aspect ratio 3.5 and taper ratio 0.25 used in this investigation was constructed entirely of steel polished to a high finish with the panel juncture at 0.50b/2. The inboard panel was swept back 60° 48' and the outboard panel was swept forward 60° 48' with reference to the quarter-chord line. Airfoil sections - measured parallel to the free stream - were NACA 64A005. A drawing of the wing plan form with pertinent dimensions is presented in figure 1.

TEST TECHNIQUE

This investigation was conducted in the Langley high-speed 7- by 10-foot tunnel by using a small reflection plane over which high subsonic and low supersonic Mach numbers are obtained. A photograph of the reflection plane with a model in the test location is presented as figure 2. The presence of the reflection plane in the tunnel created high local velocities at the high tunnel Mach numbers. No appreciable gradients over the plate were noticeable through a Mach number of 0.93. (See fig. 3.) Above this Mach number, the gradients increased to an average chordwise value of 0.05 at a Mach number of 1.10. For a more detailed description and explanation of this test technique, see references 1 and 2.

Force and moment data were obtained from a strain-gage balance system. The angle of attack was varied remotely from -10° to 17°. Mach numbers ranged from 0.70 to 1.10 and the Reynolds numbers (based on $\bar{c}$) were of the order of 850,000. (See fig. 4.)

Air leakage effects around the butt of the model were minimized by attaching a sponge seal at the root chord which was mounted so as to lightly touch the inside of the reflection-plane surface.

RESULTS AND DISCUSSION

The basic data of this investigation are presented in figure 5. Variation of angle of attack, pitching moment, and drag due to lift (see fig. 6) are presented against lift coefficient for a Mach number of 0.80 for both the W-wing and a comparable swept wing. A Mach number of 0.80 was chosen for purposes of comparison since this was the highest Mach number and lowest Reynolds number investigated on the sweptback wing with a lift range similar to that obtained on the W-wing. Caution should be exercised in evaluating the effects of plan-form modification since the Reynolds number difference between the W-wing and sweptback wing is large. The variation of lift-curve slope, pitching-moment slope, lateral center of pressure, and minimum drag with Mach number are given in figure 7. Theoretical incompressible span-load characteristics for both the W-wing and a comparable sweptback wing are also presented. (See fig. 8.)

Although the angle-of-attack range was somewhat restricted for this investigation and does not give a complete picture of the high-lift pitching-moment characteristics, within the lift range investigated, very little difference in the magnitude of the pitch-up tendency is realized between Mach number of 0.70 and 1.10 (fig. 5). However, the inflection lift coefficient - the lift coefficient at which the unstable tendency is initiated - did increase somewhat with Mach number. A comparison with the pitch characteristics at a Mach number of 0.80

(see fig. 6) of a 6-percent-thick sweptback wing having the same sweep, aspect ratio, and taper ratio as the subject wing indicated that the W-wing markedly reduced the severity of the C_m break in the lift range for which comparable data were available.

There was only a slight increase in lift-curve slope with Mach number for the W-wing. Lateral center-of-pressure locations also remained essentially constant with Mach number. (See fig. 7.) A comparison of the variation of lift-curve slope with Mach number for the W-wing and sweptback wing shows that the swept wing has about an 11 percent higher slope from Mach number 0.70 to 0.925.

Minimum drag characteristics of the W-wing indicate relatively low drag at low supersonic speeds. At a Mach number of 1.00, for example, $C_{D_{min}}$ is only about 0.0035 higher than at the lowest subsonic speeds obtained. An estimate of the pressure drag of a sweptback wing having the same nominal sweep angle and thickness ratio (as determined by the charts presented in ref. 4) indicates about a 0.0035 increase in minimum drag at a Mach number of 1.00. Thus it is seen that at this speed the sweep effect is essentially maintained on the W-wing. For both the W-wing and the swept wing, values of the drag due to lift C_{D_L} at a Mach number of 0.8 were slightly smaller than the product of the lift coefficient and the tangent of the angle of attack (fig. 6), indicating that a small amount of leading-edge suction was obtained. The curves in figure 6 are fairly representative of the drag due to lift and the amount of suction developed on the W-wing throughout the Mach number range investigated. Drag due to lift at a Mach number of 0.80 was somewhat higher for the W-wing due in part to a slightly lower lift-curve slope. Some differences in lift-curve slope and drag due to lift may be attributable to scale differences.

Span-load characteristics (fig. 8) were computed by the method presented in reference 5 for the W-wing and determined for the swept wing from the charts presented in reference 6. A comparison of the theoretical incompressible span-load distribution of the W- and swept wing of figure 8 indicate that the W-wing should support a much larger percentage of the total load on the inboard sections than the swept wing. Theoretical incompressible-flow estimates (see fig. 8) indicate essentially the same value of lift-curve slope for both the sweptback and subject wing. Correcting the theoretical estimate of lift-curve slope of the W-wing for the effects of compressibility at a Mach number of 0.70 gave a value of lift slope of 0.045, which is about 7 percent higher than experiment. (See fig. 7.) Theoretical W-wing estimate of lateral center-of-pressure location (0.40b/2) was some 2 percent outboard of the experimental value at Mach number of 0.70. (See fig. 7.)

CONCLUDING REMARKS

The results of the present wind-tunnel investigation to determine the transonic aerodynamic characteristics of a W-wing with an aspect ratio 3.5, taper ratio 0.25, 60° 48' panel sweep compared with swept-wing data indicate the plan-form modification markedly reduced the severity of the pitching-moment break. Minimum drag characteristics indicated a relatively low drag at supersonic speeds; an estimate of the minimum drag at a Mach number of 1.00 indicates a major portion of the sweep effect was still retained. The drag due to lift of the W-wing was slightly higher than that of the swept wing at the lower subsonic Mach numbers at which comparable data were available. Part of this increase in drag due to lift may be due to the lower Reynolds number of the W-wing.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., June 5, 1953.

REFERENCES

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2. Campbell, George S., and Morrison, William D., Jr.: A Small-Scale Investigation of "M" and "W" Wings at Transonic Speeds. NACA RM L50H25a, 1950.

3. Reynolds, Robert M., and Smith, Donald W.: Aerodynamic Study of a Wing-Fuselage Combination Employing a Wing Swept Back 63°.- Subsonic Mach and Reynolds Number Effects on the Characteristics of the Wing and on the Effectiveness of an Elevon. NACA RM A8D20, 1948.

4. Polhamus, Edward C.: Summary of Results Obtained by Transonic-Bump Method on Effects of Plan Form and Thickness on Lift and Drag Characteristics of Wings at Transonic Speeds. NACA RM L51H30, 1951.

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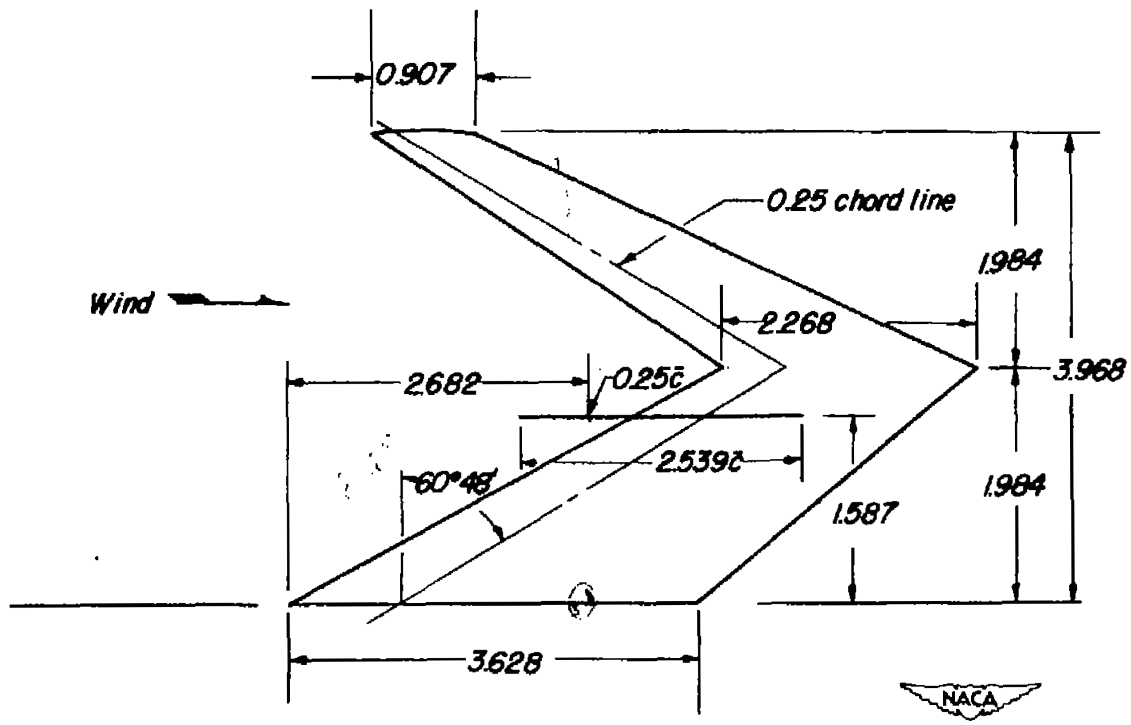
6. DeYoung, John, and Harper, Charles W.: Theoretical Symmetric Span Loading at Subsonic Speeds for Wings Having Arbitrary Plan Form. NACA Rep. 921, 1948.



TABULATED WING DATA

Area (Twice semispan)	0.125 sq ft
Aspect ratio	3.500
Taper ratio	0.250
Airfoil section parallel to free stream	NACA 64A005

Figure 1.- Plan-form drawing of a W-wing having 60° 48' panel sweep, aspect ratio 3.5, taper ratio 0.25, and NACA 64A005 airfoil sections. All dimensions are in inches except where otherwise noted.

Figure 2.- Reflection-plane installation with W-wing mounted. L-64860.1

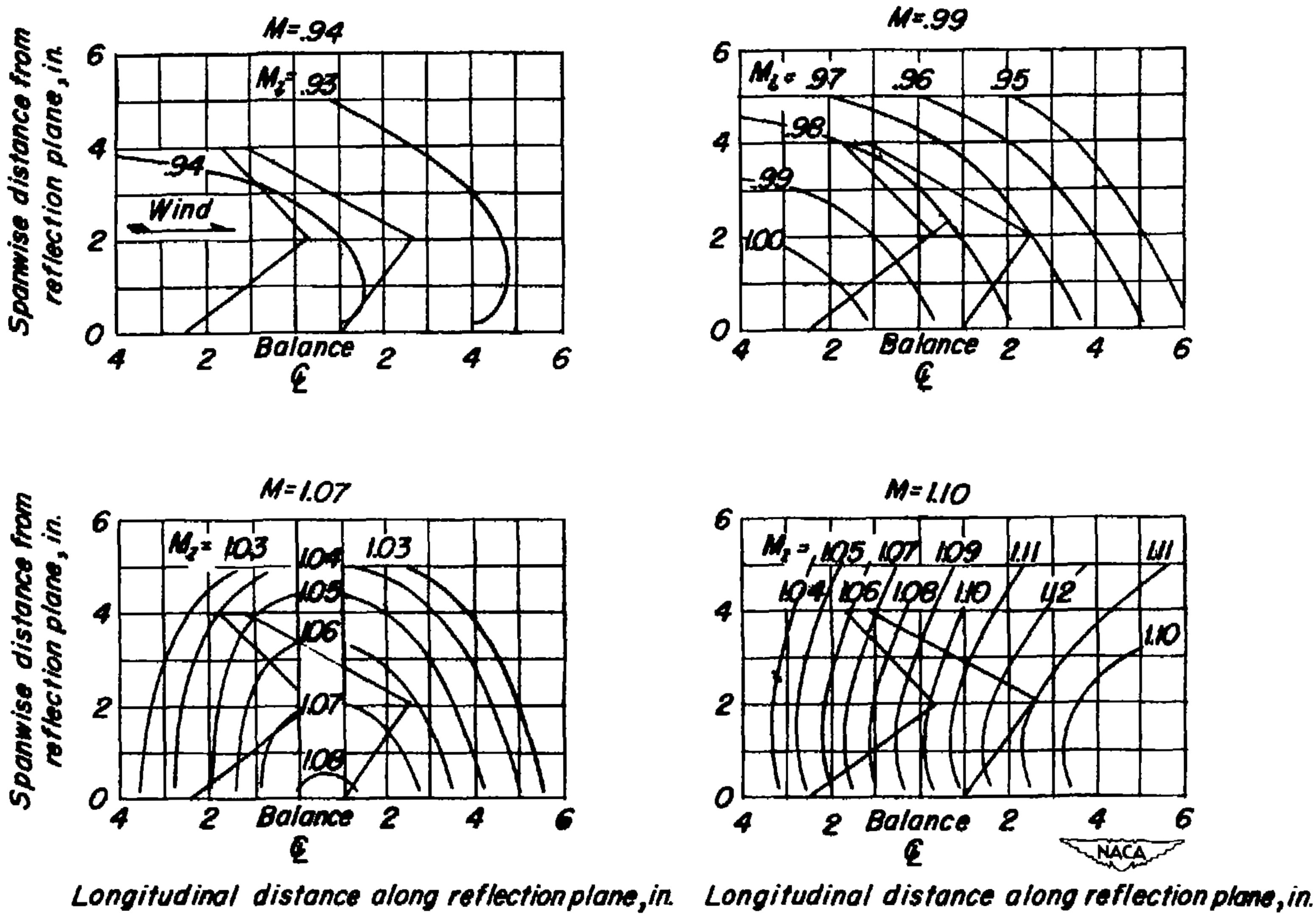


Figure 3.- Typical Mach number contours in the testing region of the semispan model.

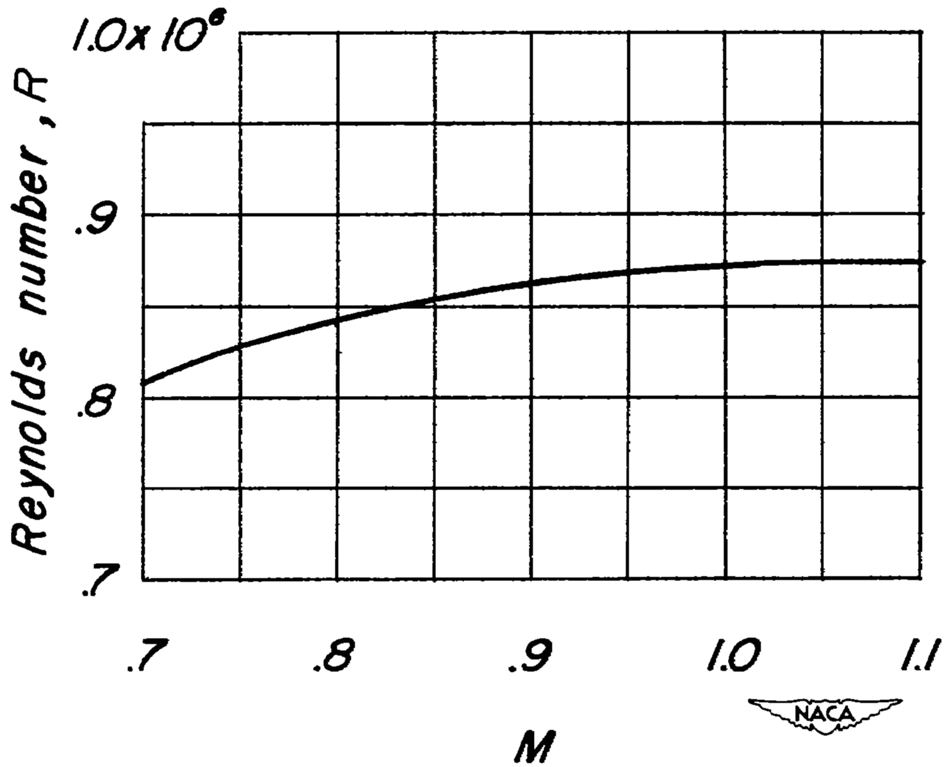
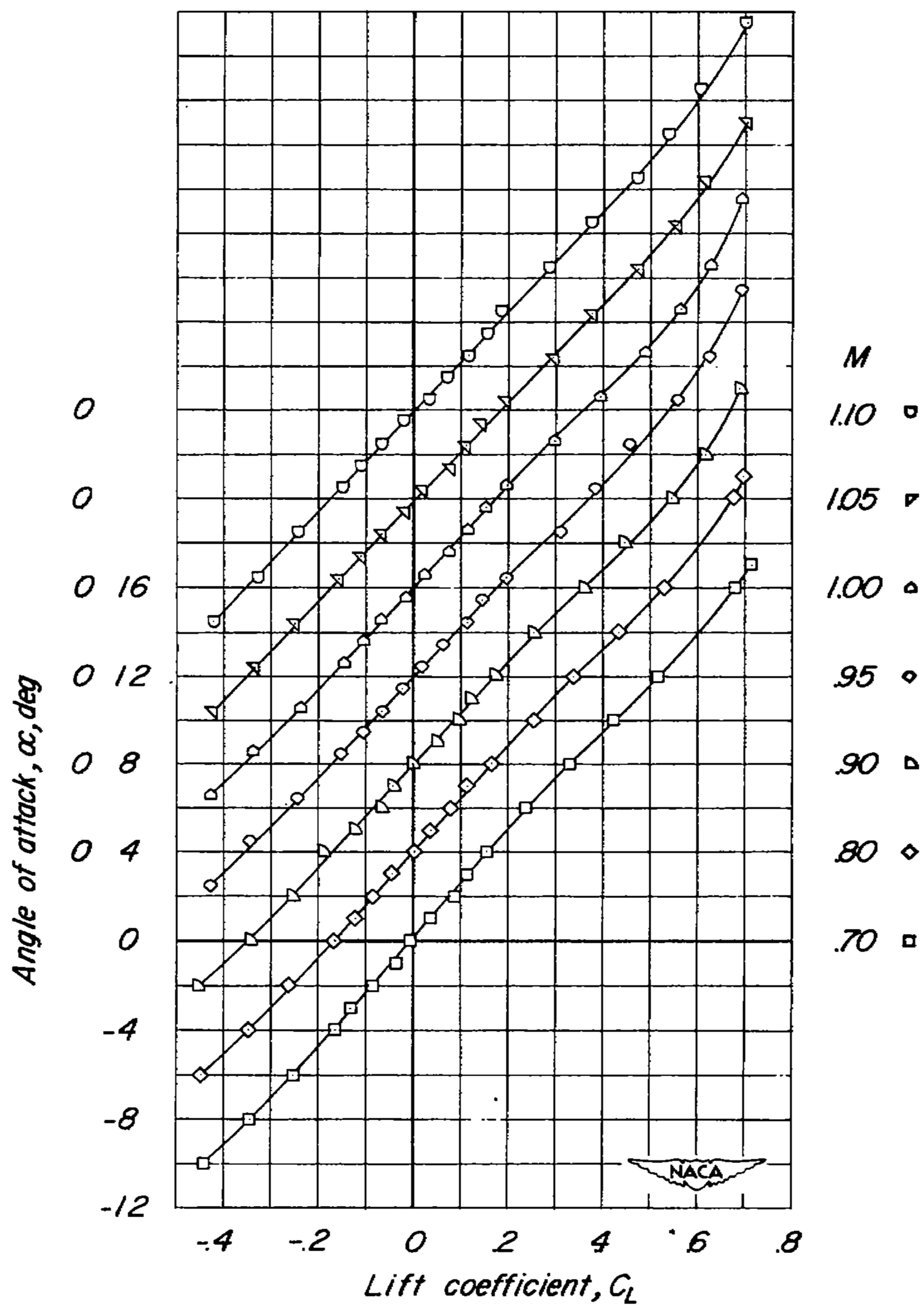
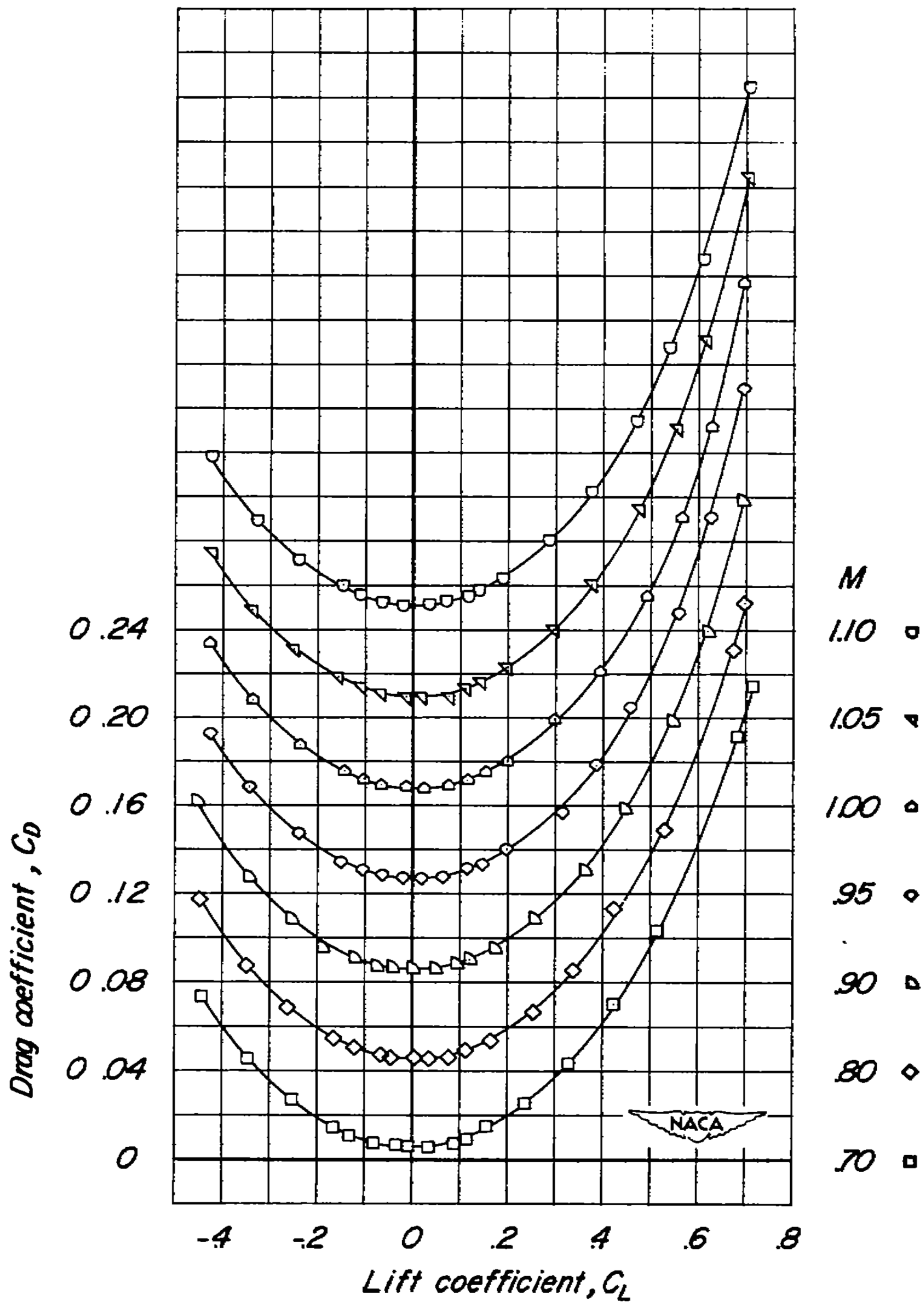


Figure 4.- Variation of mean Reynolds number with Mach number for a W-wing having 60° 48' panel sweep, aspect ratio 3.5, and taper ratio 0.25.



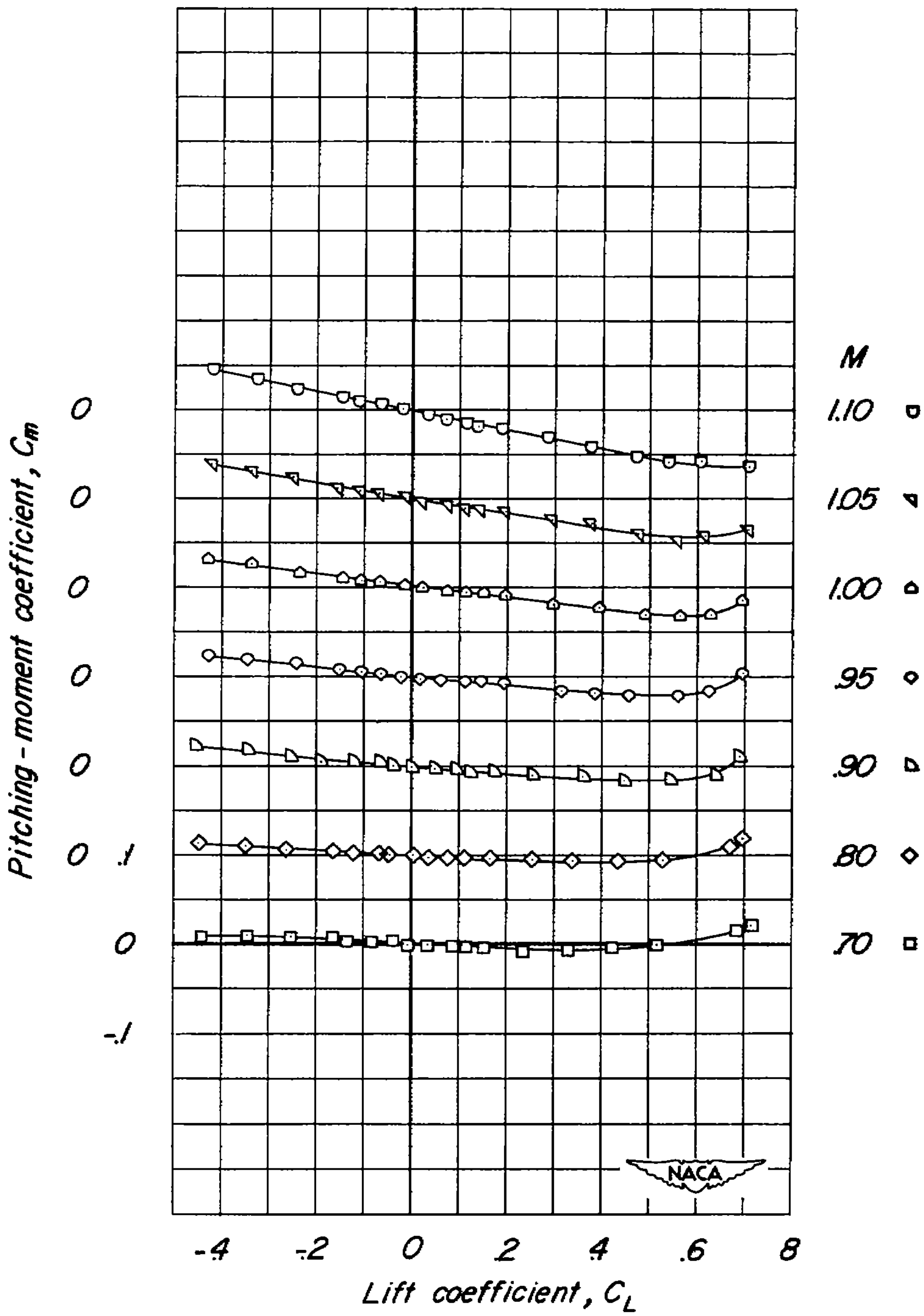
(a) α against C_L.

Figure 5.- Transonic aerodynamic characteristics in pitch of a W-wing model having 60° 48' panel sweep, aspect ratio 3.5, taper ratio 0.25, and NACA 64A005 airfoil sections.



(b) C_D against C_L.

Figure 5.- Continued.



(c) C_m against C_L.

Figure 5.- Continued.

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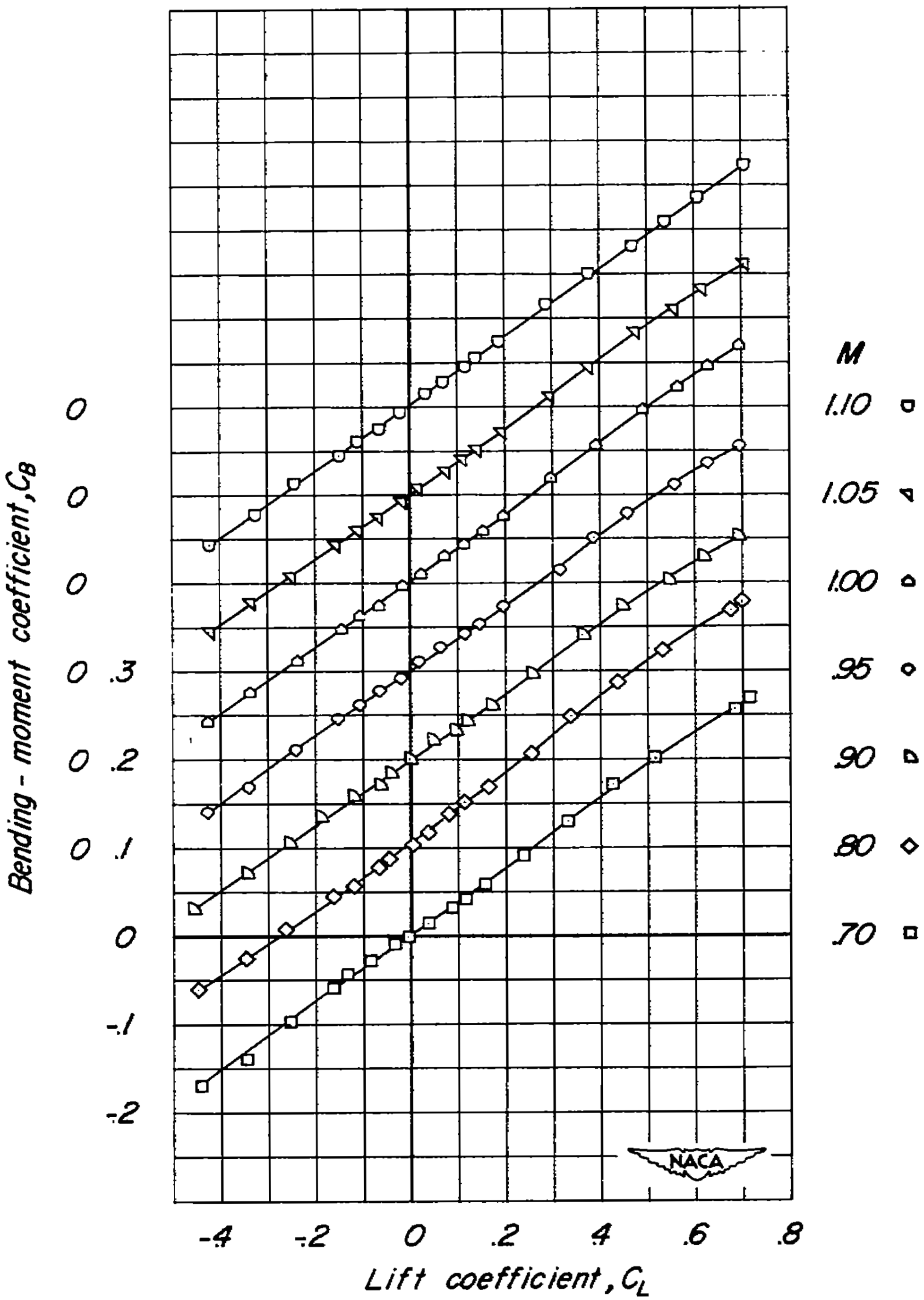

(d) C_B against C_L.

Figure 5.- Concluded.

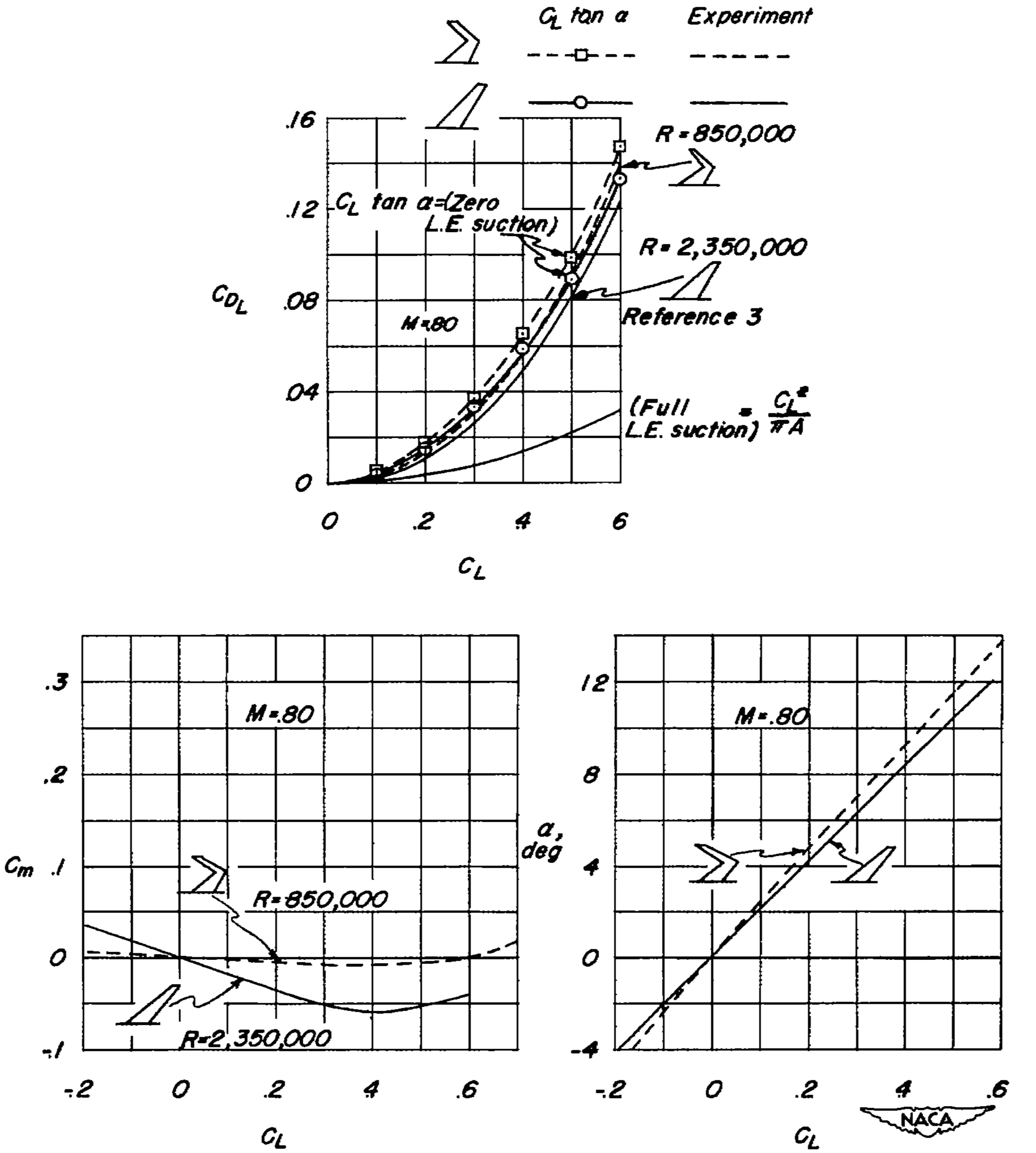

Figure 6.- The variations of pitching moment, angle of attack, and drag due to lift with lift coefficient at a Mach number of 0.80 for a W-wing and swept wing having 60° 48' sweep of the quarter-chord line, aspect ratio 3.5, and taper ratio 0.25.

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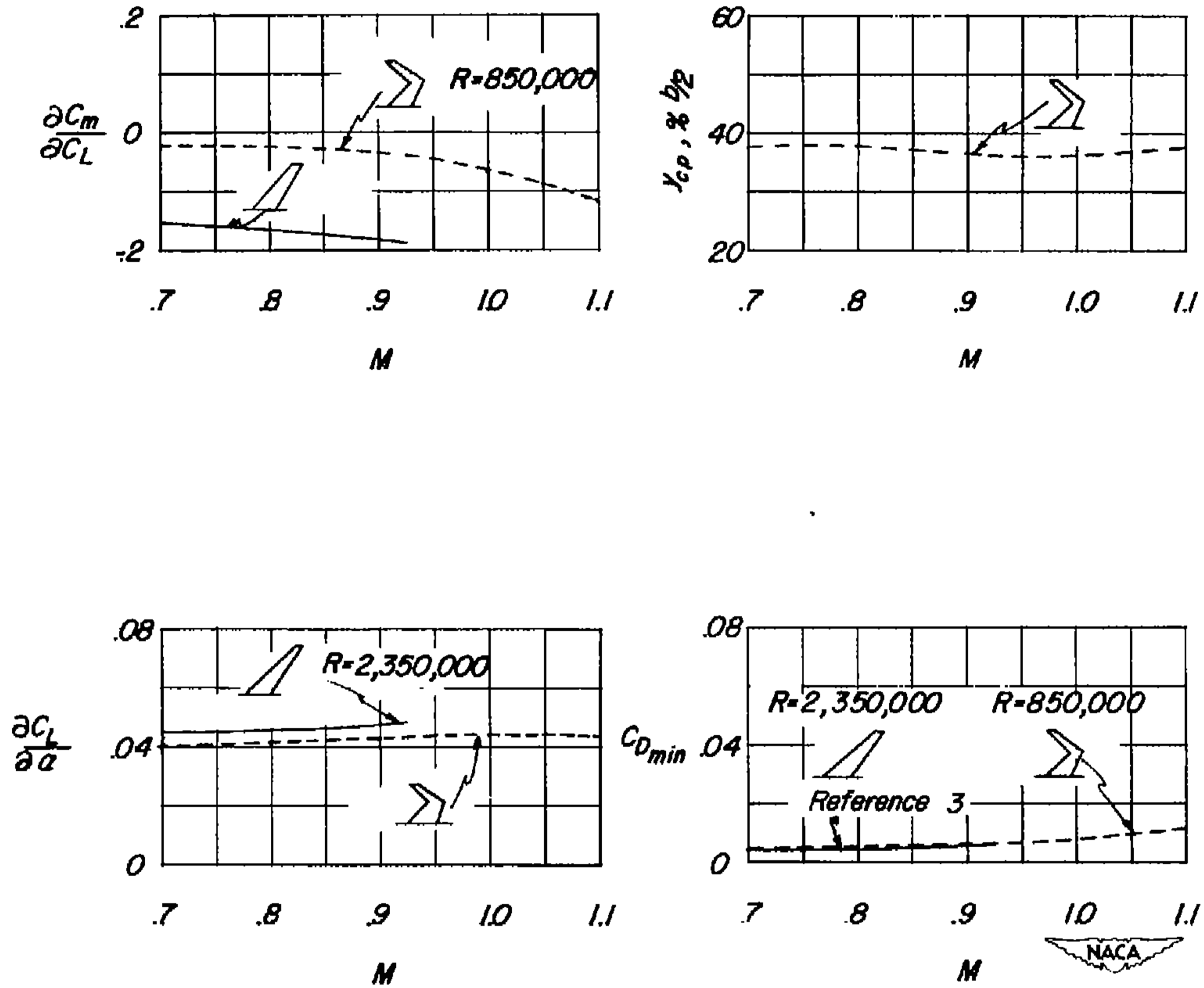

Figure 7.- The variations of the aerodynamic characteristics with Mach number of a W-wing and swept wing having 60° 48' sweep of the quarter-chord line, aspect ratio 3.5, and taper ratio 0.25.

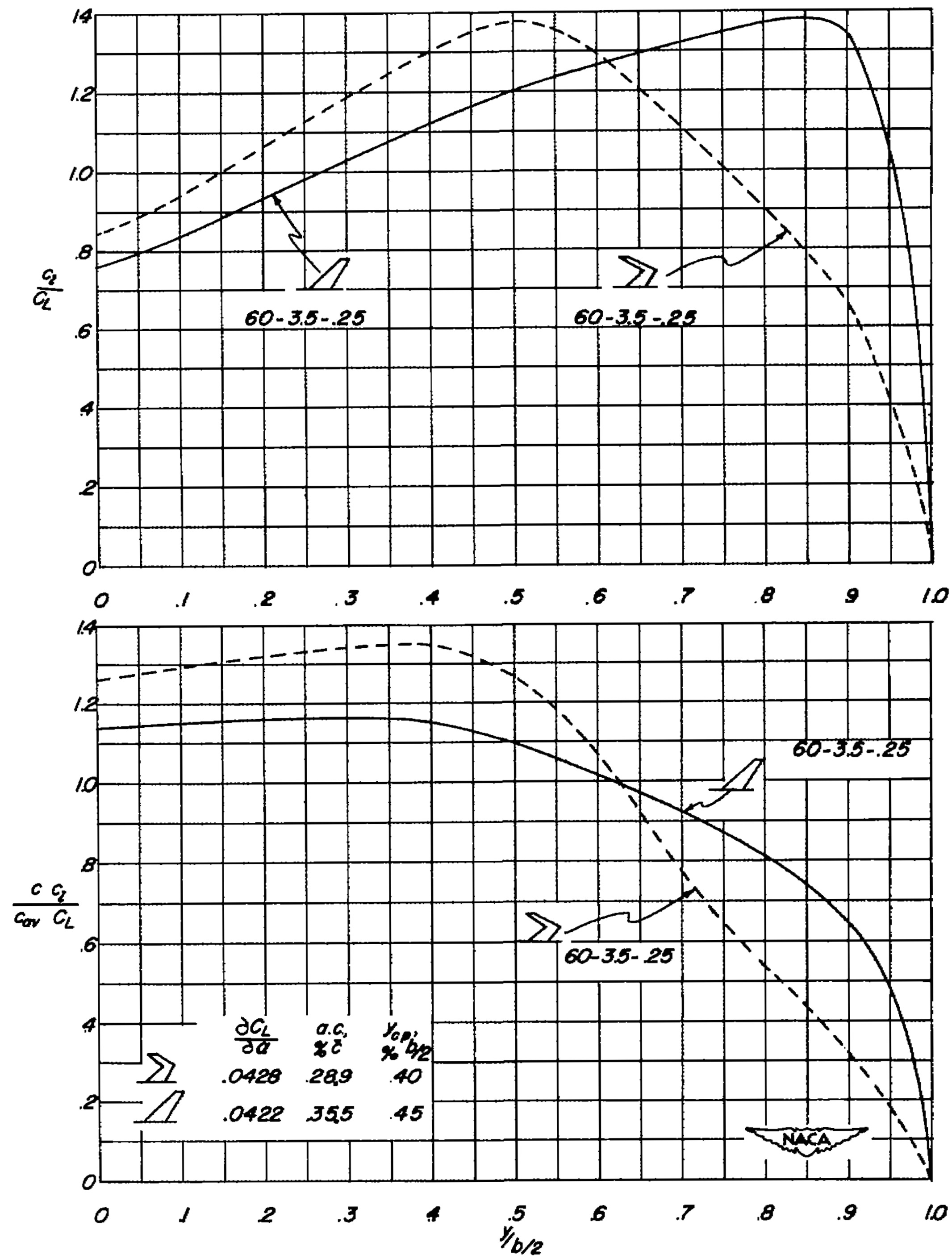

Figure 8.- Theoretical incompressible span-load characteristics of a W-wing and sweptback wing having 60° 48' sweep of the quarter-chord line, aspect ratio 3.5, and taper ratio 0.25.

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